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Technical Article 1.

LORAN-C NAVIGATION

by
Charles W. Dull[1]

One of the new developments in aerial surveys and aerial photography in the USDA Forest Service has been the utilization of the Loran-C radio navigation system. Loran-C is an acronym for Long Range Aid to Navigation. This navigation system has been especially useful in southern pine beetle (SPB) aerial and ground surveys to determine locations of dead and dying timber.

Loran-C can be used to increase the efficiency of aerial surveys, decrease the effort by ground crews in locating SPB spots that have been detected from the air, and ultimately reduce survey costs. It aids in navigation and position determination during SPB surveys and could perform a variety of other forest-related applications as well.

Loran-C is a pulsed, low-frequency, hyperbolic, radio navigation aid that uses synchronized signals from three or more Loran ground stations to obtain a position fix. A master ground station transmits the signal. Two or more secondary transmitting stations receive the signal and use it to synchronize their transmitters. At the proper time interval, each transmits a signal which is received in the aircraft. These signal characteristics permit the equipment to be used in the air and on the ground at great distances (1200 mi) from the transmitting station. Loran-C can compute the position, with an update twice every second.

[1]Entomologist, USDA Forest Service, Forest Pest Management, Aerial Survey Team, 3620 Interstate 85, N. E., Room 2103, Doraville, Georgia 30340

The Loran-C system enables a pilot and survey crew to determine their positions accurateately and also to resurvey the same areas with precision. Navigation to a waypoint for which the coordinates have been obtained from a map may provide a position accuracy within a fourth of a mile of the waypoint. But once the actual Loran coordinates for the waypoint position have been obtained, the return accuracy of the navigational display may be within as little as 50 feet.

The Loran-C receiver can be interfaced with an onboard navigational cómputer to provide aircraft guidance and conversion of Loran time-difference coordinates into latitutde and longitude.

PREPARING FOR AN AERIAL SURVEY OR AERIAL PHOTOGRAPHIC MISSION

After the boundaries of a survey area have been established, parallel flight lines can be drawn on the survey map at predetermined intervals, depending on the survey or photographic coverage desired. One of the flight lines should be drawn on a known line of latitude or longitude to establish a base leg with known beginning-point and end-point coordinates. The distance from the base leg to each parallel flight line is then determined in nautical miles. The parallel flight lines are "offset" left or right of the base leg, depending on which direction the line is to be flown.

A workable navigational readout requires the following:

1. Starting point. Usually the position of the aircraft at the airport is sufficient. The latitude/longitude can be obtained from the airport directory.

2. Select the chain. A Loran-C chain is comprised of a group of three to five transmitting stations. One station is designated as the

master station and the others are designated as secondary stations.

3. Secondary stations. Two secondary stations must be selected to provide the best coverage for the survey area. Many Loran-C chains have more than two secondary stations from which you can choose the best coverage. Some Loran-C receivers automatically select the secondary stations that provide the best signal.

GENERAL DISCUSSION

A pilot or experienced observer/tracker can be taught to program the Loran-C airborne system in one or two missions. After the system has been programmed and the survey is ready to be implemented, a variety of navigational data is computed.

A major advantage of Loran-C is the reduced time required to position the aircraft on a flight line prior to entering the survey area. Once on the flight line, the pilot can more accurately follow the desired line. The pilot is not required to make continual references to a flight map, thus, he can direct his attention to the flight path. This is an important safety factor. The flight crew will experience less survey fatigue because they can concentrate fully on their job without the worry of visual navigational accuracy.

Loran-C can aid in photographic surveys, too. The increased accuracy of following parallel flight lines provides greater control of sidelap, reducing the likelihood of gaps between photo lines. Sequential photography for sampling trends or loss assessment over time is not difficult when Loran is used.

An airborne Loran-C navigation system with prestored search patterns and a data link system costs about $30,000. A smaller system without the prestored search pattern and data link system costs $12,000. This expenditure, while substantial, is offset by savings in flight time and survey effectiveness. Other navigation systems providing greater accuracy are available at higher costs.

Loran-C transmitting stations provide good coverage of the East, Gulf, and West Coasts with additional coverage around the Great Lakes area. The mid-western area of the United States does not have Loran-C coverage at this time, although plans are underway to provide complete coverage to the entire U.S. by the mid 1980's.

There are other applications for the Loran-C navigation and position determination system. In forestry alone, they could include aerial applications of pesticides and fertilizers, spray analysis, search and rescue operations, trail mapping for use in wildlife and migration studies, vehicle monitoring, and forest fire suppression. Fire control activities employing Loran-C could include locating the position of a fire, dispatching firefighters, airdropping retardants and supplies, and monitoring the locations of crews and equipment. Additional information is available from the author.

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Technical Article 2.

HOW TO OBTAIN LARGE BASAL AREA FACTORS WITH AN AMERICAN SCALE SPIEGEL RELASKOP

by
Douglas Jager[1]

The Spiegel Relaskop is widely used for measuring a variety of tree and stand parameters. Here our interest lies in its use as a slope-compensating angle gage for point sampling. Instructions provided by the manufacturer indicate that the American scale Relaskop offers a choice of four basal area factors (BAF). These are 5, 10, 20, and 40 square feet per acre per tree. In many stands larger basal area factors are desirable. This paper demonstrates the availability of six larger basal area factors on the American scale Relaskop. These are 46.94, 54.44, 62.50, 71.11, 80.28, and 90.00. Readers are advised to round to nearest one-half BAF and measure distance to near-borderline trees. Larger angles are also available in the metric scale and wide scale model Relaskops.

Readers accustomed to point sampling and measuring diameters with the American scale Relaskop will recall the six narrow diameter bars between "a" and "b" and the wider diameter and basal area bars between "0" and "a". In diameter units the scale "0-a" is equivalent to 12 diameter bars (twice the "a-b" scale). Note also that the diameter equivalent of each of the six narrow bars (between "a" and "b") is 1/198 of the horizontal distance between the observer and the central axis of the target tree. Thus, at a horizontal distance of 33 feet the diameter equivalent of each narrow bar is 2 inches, "a-b" is 12 inches, and "0-a" is 24 inches. Thus "0-b" is 36 inches.

Picture a 24-inch-diameter tree viewed with the "0-a" scale. Intuitively we can show that this tree represents 40 square feet per acre. (The "0-a BAF is 40). In point sampling this tree is borderline at a horizontal distance of 33 feet. This borderline plot is 3,421.194 square feet and there are 12.732 of these borderline plots in each acre. Thus, this tree has a stand table factor (STF) of 12.732 and represents 12.732 trees per acre. A 24-inch tree has a

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[1]Associate Professor Forestry, Dept. of Forestry, School of Natural Resources, Humboldt State University, Arcata, CA 95521

basal area of 3.142 square feet and 3.142 times 12.732 equals 40. Therefore the "0-a" BAF is 40. That is, this tree represents 40 square feet per acre.

Using this technique, we can increase the size of the angle gage by adding the six narrow diameter bars between "a" and "b", one at a time. For example, consider the "0-a" scale plus one narrow diameter bar (a total of 13 diameter bars). At a horizontal distance of 33 feet, the corresponding tree has a diameter of 26 inches and a basal area of 3.687 square feet. Because the tree is borderline at 33 feet the STF is still 12.732. Therefore, the calculated BAF is 46.94 (3.687 x 12.732). Similar calculations have been determined for the remaining five narrow diameter bars.

Results are shown in Table 1. The appropriate plot radius factor (PRF) is shown for each BAF. The PRF may be calculated by:

$$PRF = 8.696/BAF^{0.5}$$

For any given tree the borderline plot radius (BLPR), horizontal distance from borderline tree center to observation point can be calculated by:

$$BLPR\ (feet) = PRF \times DBH\ (inches)$$

Readers that prefer not to use the intuitive approach described above can calculate the appropriate BAF for any number of diameter bars by:

$$BAF = 43560/(198/(NO.\ DIAMETER\ BARS \times 0.5)^2$$

For 13 bars:

$$\begin{aligned} BAF &= 43560 / (198/(13 \times 0.5)^2 \\ &= 43560 / (198/6.5)^2 \\ &= 43560 / 927.905 \\ &= 46.94 \end{aligned}$$

Table 1. Large basal area factors and related plot radius factors for the American scale Relaskop obtained by adding the six narrow bars between "a" and "b"[1] to the 12 diameter bars on the "0-a" scale.[1]

Scale	Plus					
"0-a"	1 bars	2 bars	3 bars	4 bars	5 bars	6 bars
BAF	46.94	54.44	62.50	71.11	80.28	90.00
PRF	1.269	1.179	1.100	1.031	0.971	0.917

[1]Readers are cautioned that the PRF's are for the indicated BAF's. If the reader chooses to round a BAF off, a new PRF must be calculated. For example, the PRF associated with a 47 BAF is 1.268.

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Technical Article 3.

THE LANDFORM COMPONENT IN LAND CLASSIFICATION

by

Robert G. Bailey[1]

Although landform is recognized as an important component of the Component Land Classification for the United States, no single system of classification has been found to be acceptable. A spatial classification is being developed along both genetic and empirical lines which will be field tested for usability.

INTRODUCTION

The Component Land Classification for the United States (Merkel et al., in preparation) has four components: vegetation, soil, landform, and water. The authors of the classification document clearly recognize that further work is needed to develop and implement the landform component, particularly at the lower levels. As a result of review and testing of the Classification, it has become apparent that fundamental questions remain unanswered regarding the need for a landform component and the appropriateness of the approach. This is due, in part, to the absence of either a generally accepted method for description or a framework for classifying landform, and to the lack of a clearly perceived role for such a classification. Unlike the classification system for soils, the current approaches to landform classification have not gravitated toward a common system. Several systems have gained a following in the United States; these appear to be tied to traditional systems based on developmental (genetic) properties or to more current systems based on inherent (empirical) properties, such as surface configuration. However, no single system appears to be acceptable in all respects.

The purposes of this paper are to review briefly the role of landform in land classification, to outline the logic of the two major approaches, and to discuss how to decide which approach is best for resource assessment and planning.

THE ROLE OF LANDFORM IN LAND CLASSIFICATION

Landforms are units of the distinctive configuration of the land surface: mountains, hills, valleys, plains, and the like. Landforms are environmentally significant because they influence the place-to-place variation in ecological factors such as water availability and

[1]Geographer, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, CO 80526, in cooperation with Colorado State University.

exposure to radiant solar energy. Through varying height and degree of inclination of the ground surface, landforms interact with climate and directly influence hydrologic and soil-forming processess; these, in turn, act as direct controls on ecosystems. Thus, landforms are an essential part of any classification of land on an ecosystem basis.

LANDFORM CLASSIFICATION

The earth's landforms have been classified in a variety of ways. There is no one method which is best, because some are better for one purpose and some for another. Nevertheless, as classifications they all have the same goal: to reduce innumerable local landforms to a relatively few types with important characteristics in common.

Any classification presupposes individuals or units which are grouped to form classes; however, climate, soils, and landforms are difficult to classify because they vary along a continuum and are not composed of discrete natural units. In climatic classification the individuals classified are climatic conditions at specific points as revealed by the reports of weather stations. Landform, however, is a spatial concept, and "point" values, even where they are available, do not give a meaningful sample of conditions over large areas. Landform classification, then, requires that the characteristics upon which the classification is to be based be those of areas, as well as the individual features which give them their distinctive character.

A study of inherent characteristics of landforms involves other problems which are analogous to those encountered in the description of climate. Both are really complexes, not solitary phenomena; consequently, it is necessary to reduce them to component characteristics if they are to be analyzed and compared.

A key problem for land classifiers concerns the kind of characteristic or properties of landforms that guide the classification process. As Rowe (1979) points out, we can distinguish two kinds of properties: inherent and developmental.

Inherent Properties as a Basis for Classification

Inherent properties are taxonomic or factual properties by which, for example, certain landforms are classified as "dunes" on the basis of shape and materials. Characteristics considered to be factual mostly pertain to morphology (i.e., to form, structure, anatomy, and related qualities). Such an approach is empirical because it is based on properties which are directly observable (such as slope).

Hammond developed a landform map of the country on this basis for the U.S. National Atlas (U.S. Department of Interior, Geological Survey 1970). The Hammond system is strictly empirical; that is to say, each landform is defined according to fixed values of slope, relief, pattern, and material. A landform system based on these principles shows the surface as an array of clearly defined types that can occur repetitively and can be compared and contrasted in terms of specific attributes. This approach has been successfully employed and has become standard procedure for the classfication of such complex phenomena as climate and soil. A more comprehensive treatment of the approach appears in Hammond (1964).

Developmental Properties as a Basis for Classification

Developmental properties are genetic or chronologic properties that are inferred from a variety of evidence. In the earth sciences, certain landforms may be classed together on similarities of genesis as "alluvium" or "colluvium." Note that in these examples the things that are classified according to genetic or developmental relatedness are sometimes dissimilar in inherent properties. For example, both deep stream-cut canyons and huge alluvial fans are classified as fluvial forms.

A primary goal of genetic landform classification is to provide an explanation of how a particular form has evolved to its present state. As such, it is basically an interpretation of the genesis of landforms, not the forms themselves.

William Morris Davis introduced the study of landforms according to their origin and stage of development in about 1890. The landform classification in earlier versions of the Classification was an expansion of Davis' system and followed closely one presented by Fairbridge (1968).

DISCUSSION

In classifying landforms, we must ascertain those aspects which are of greatest significance to the purpose at hand. For most resource assessment and planning purposes, a landform classification should recognize actual characteristics of the existing surface and subsurface, rather than genetic interpretations. Those who are concerned with the relationship of the landform pattern to other patterns, physical or cultural, are more often concerned with the present form of the surface and the materials under it than with the origins of that form. Furthermore, genetic characterizations suffer from being essentially theoretical, often grossly inaccurate, especially in the less-well-known areas, and sometimes very misleading. Such terms as "piedmont," "hanging valley," "dissected plateau," and "fold structures" are ambiguous when used to characterize landform.

For purposes of identifying areas which will respond similarly to management practices, the

genetic approach alone is irrelevant. It is just simply not genesis that matters here; it is slope, shape, surface materials, and all the other things that affect runoff, infiltration, slope stability, productivity, operability, etc., that matter. It is current function, not the interpretation of origin, that is important for these purposes.

On the other hand, genetic interpretation can be very useful. A wholly systematic classification of landforms based on inherent properties such as slope and relief would never arrive at the unit "floodplain," because it is a pattern of spatially associated but unlike components. The unit known as a floodplain only comes into existence through the understanding of a significant process. It cannot be discovered by simply merging categories of similar things. Genesis, therefore, must be taken into consideration so as to identify important functional units of the landscape.

For a more detailed discussion of empirical landform classification and its relationship to the genetic approach, see Zakrzewska (1971). Murphy (1968) developed a classification of landforms based on both approaches and applied it on a worldwide scale.

CONCLUSION AND NEEDS

Landform is an integral and essential part of land classification. A spatial classification which is based in part upon the actual configuration of the land surface and in part upon genesis (origin) of landforms would appear to be both appropriate and meaningful in terms of the discussion above. Some work toward such a classification has been done on a worldwide scale. Much work remains to be done to increase the resolution of such an approach so as to provide a landform data base for national assessments that will also have utility for planning at regional and local levels. The genetic factors used should be those which are not mere speculations or hypothesis but rather those of generally accepted geological record. The empirical factors should be chosen with an eye to simplicity.

Prior to development of such a scheme the following needs must be met:

1. Develop a conceptual framework for testing the effectiveness of these classifications for resource assessment and planning purposes.

2. Evaluate further the feasibility and necessity of a landform classification scheme that will compatibly incorporate both genetic and empirical factors.

A plan for addressing these needs has been adopted by the Interagency Strategy Group on Landform Classification. This plan is being implemented through an agreement between the Forest Service and Colorado State University with funding from the Geological Survey. Field testing and evaluations are under way.

Acknowledgments

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Literature Cited

Fairbridge, Rhodes W. 1968. Land mass and major landform classification. p. 618-626. In The Encyclopedia of Geomorphology, R.W. Fairbridge, editor. Reinhold, New York, N.Y.

Hammond, Edwin H. 1964. Analysis of properties in land form geography: An application to broad-scale landform mapping. Annals Association American Geographers. 54:11-23.

Merkel, D. L., R. S. Driscoll, J. S. Hagihara, D. O. Meeker, D. E. Snyder, and T. T. Terrell. In prep. A component land classification for the United States - status and plans. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Murphy, Richard E. 1968. Landforms of the world. Annals Association American Geographers. 58:Map Supplement 9.

Rowe, J. S. 1979. Revised working paper on methodology/philosophy of ecological land classification in Canada. p. 23-30. In Proceedings Second Meeting Canada Committee on Ecological (Biophysical) Land Classification. C.D.A. Rubec, editor. [Victoria, B. C. April 4-7, 1978] Lands Directorate, Environment Canada, Ottawa, Ontario, Canada.

U.S. Department of Interior, Geological Survey. 1970. Classes of land-surface form in the United States. U.S. National Atlas Sheet 62. Washington, D.C.

Zakrzewska, Barbara. 1971. Nature of land form geography. Professional Geographer. 23:351-354.

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Technical Article 4.

IMPROVED ESTIMATES THROUGH SAMPLE SELECTION AND ESTIMATION

by
Hans T. Schreuder and H. Gyde Lund[1]

ABSTRACT

Potential gains in estimating total cubic foot volume of a population are illustrated using tree diameter (D) or transformations of D (D^2 and $1/D$) as covariates for stratification or in simple linear regression. A population of 1080 white oak trees on which cubic foot volume (V) and D were measured is used. The importance of using the correct covariate is emphasized.

Two statistically acceptable approaches are practical for improving the reliability of estimates such as the attempt to ascertain how much wood (cubic foot volume) is on a tract of land. Improved reliability refers to the ability to have our estimate be closer to the true amount of wood on the tract. Increasing sample size, although statistically acceptable, is usually not a practical alternative.

The first approach, efficiency in sample design, attempts to assure that the sample actually obtained gives an estimate closer to the true amount than other samples that might be used worth no greater effort or cost. Hence, simple random sampling is considered undesirable in this context since both desirable (those yielding estimates close to the desired total) and undesirable samples have equal probability of selection. Systematic sampling is better in this sense because, by spreading the sample out over the population, our estimate will often be closer to the true amount than estimates based on simple random sampling. Stratified sampling, sampling with probability proportional to size (pps sampling), or model-based sampling (Schreuder 1980)[2] can be more efficient designs.

The second approach uses improved estimators that rely on some relationship between the variable of interest (y) such as tree volume and one or more easy-to-measure variables, covariates (x) such as tree diameter that are not of interest themselves, to reduce variance and mean-square error.

Ratio and regression estimators are examples of improved estimators using covariate information. Simple means or total estimates do not use covariate information. The better the relationship between y and x is known, the better one can do in estimation by relying on that specific relationship. Data should be plotted to help determine what relationship, if any, there is between y and x.

If one is confident that the assumed relationship is a reliable approximation of the true relationship, then this information can be utilized in both design and estimation to obtain very efficient estimates (Schreuder 1980). These estimates may be seriously in error, however, if the assumed relationship is false.

The purpose of this article is to illustrate the gains and losses that can be achieved through improved design and estimation techniques applied to a well-known research forestry situation, that of cubic foot volume estimation (V_i). For illustration purposes we will use various appropriate and inappropriate transformations of the covariate tree diameter at breast height (D_i) with V_i.

Data

A data set containing volume (V_i) and diameter (D_i) for 1,080 white oak (*Quercus alba*) trees collected throughout the southeast (McClure and Schreuder 1981)[2] will be used to illustrate gains that can be achieved by sample selection and estimation. Our goal is to estimate the total cubic foot volume, V, of this population.

Methods

For these data we know that the model

$$V_i = a_1 + b_1 D_i^2, \; i = 1; \ldots, N$$

provides a strong relationship (fig. 1). Here a and b are constants estimated usually by least squares regression (Freese 1962). N is population size, 1,080 in this case. We also know that

$$V_i = a_2 + b_2 D_i; \; i = 1, \ldots, N$$

is a less appropriate model (fig. 2), and that

$$V_i = a_3 + b_3/D_i^2, \; i = 1, \ldots, N$$

is clearly inappropriate (fig. 3).

We used the following sampling strategies (Cochran 1977):

1. Simple random sampling with the usual simple estimator

$$\hat{V}_1 = N \bar{v}$$

where N = 1080, and $\bar{v}$ is the simple mean of the randomly selected tree volumes. No covariate is used here either in design or estimation.

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[1]Mathematical Statistician and Research Forester respectively, USDA Forest Service, Resources Evaluation Techniques Program, 240 West Prospect Street, Fort Collins, CO 80526.

[2]Schreuder, H. T. 1980. Forest sampling in the absence of a well-defined frame. Invited paper, American Statistical Association National Meeting, August 11-14, 1980, Houston, Texas.

[2]McClure, J. P., and H. T. Schreuder. A comparison of volume table equations for loblolly pine and white oak. To be submitted to Southern Journal of Applied Forestry.

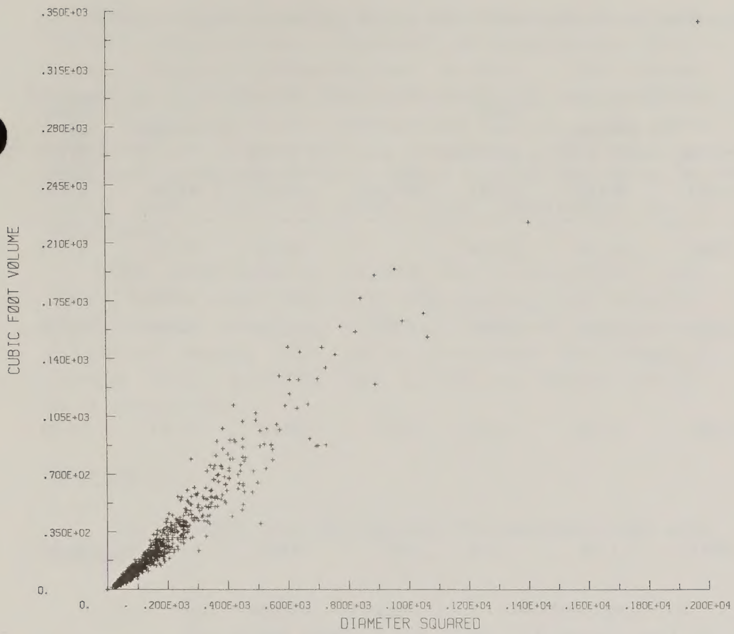

FIGURE 1. CUBIC FØØT VØLUME VS THE SQUARE ØF DIAMETER IN INCHES SQUARED FØR WHITE ØAK

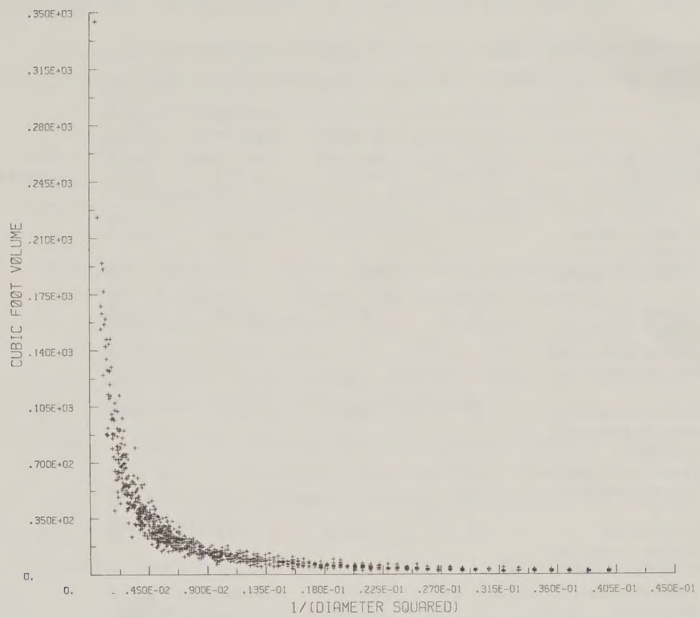

FIGURE 3. CUBIC FØØT VØLUME VS THE INVERSE ØF THE SQUARE ØF DIAMETER FØR WHITE ØAK

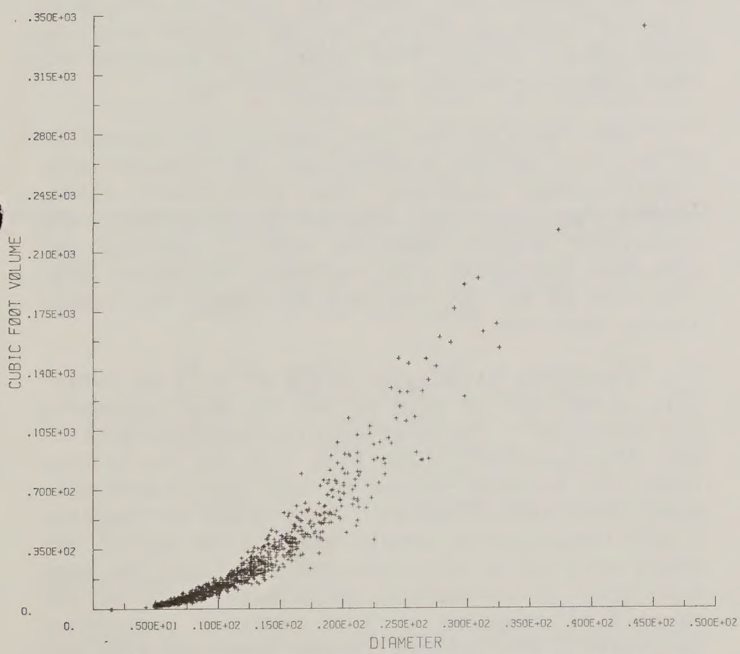

FIGURE 2. CUBIC FØØT VØLUME VS DIAMETER IN INCHES FØR WHITE ØAK

2. Stratified random sampling with the usual simple stratified sampling estimate

$$\hat{V}_2 = \sum_{h=1}^{k} N_h \bar{v}_h$$

where k = number of strata, N_h = number of trees in stratum h (h = 1, . . ., k), and $\bar{v}_h$ is the simple mean of the randomly selected tree volumes in stratum h (h = 1, . . ., k). The covariate (either D^2, D, or $1/D^2$) is used for stratification purposes only. Six strata were used, hence k = 6.

3. Simple random sampling with the regression estimator,

$$\hat{V}_3 = N(a_3 + b_3\bar{X})$$

where $\bar{X}$ is the population mean of D^2, D, or $1/D^2$, depending on which covariate is used. Coefficients a and b are estimated by simple least squares from sample data. Here the covariate is used only in estimation.

4. Stratified random sampling with the combined regression estimator

$$\hat{V}_4 = \hat{V}_2 + Nb_4\,(\bar{X} - \bar{x}_{st})$$

where $\bar{x}_{st}$ is the simple stratified sampling estimator

$$\bar{x}_{st} = \sum_{h=1}^{k} N_h \bar{x}_h/_N$$

and $\bar{x}_h$ is the simple mean of the randomly selected X-values (D^2, D, or $1/D^2$) in stratum h(h = 1, . . ., k). Coefficient b_4 is estimated as explained by Cochran (1977, p. 202). The variance estimate of V_4 is given in Cochran (p. 203). Again k is 6.

There were 2,000 samples of 30 taken from the population. We took 2,000 samples to ensure that the results are stable. Another 2,000 samples of size 30 should give results very similar to those in Table 1.

Table 1.--A comparison of estimates, variance estimates, and mean square errors used to estimate cubic foot volume for white oak (V = 25989) based on 2000 samples of size 30 using covariates shown.

Sampling strategy	Co-variate	Average est. of total	Average var. of est. (in mils)	Mean sq. error (in mils)	Co-variate	Average est. of total	Average var. of est. (in mils)	Mean sq. error (in mils)	Co-variate	Average est. of total	Average var. of est. (in mils)	Mean sq. error (in mils)
Simple random sampling (no covariate used)		26055	38.52	38.52		25786	37.14	37.18		25952	37.73	37.73
Stratified random sampling (covariate used for design)	D^2	25954	12.80	12.80	D	25855	13.47	13.47	$1/D^2$	26022	14.19	14.19
Random sampling with regression estimator (covariate used for estimation)	D^2	25991	1.62	1.62	D	25382	4.15	4.52	$1/D^2$	23983	25.67	29.69
Stratified random sampling with combined regression estimator (covariate used for design)	D^2	26074	1.11	1.12	D	25561	1.33	1.51	$1/D^2$	24915	13.99	15.14

Results and Discussion

Note that for each sampling strategy we give an average estimate, variance, and mean-square error (Table 1). Mean-square error is variance plus the square of the bias of the estimate. It reflects the actual variability between the estimate and actual value of interest better than the variance in the case of biased estimators. When the estimator is not biased, variance and mean-square error are the same (except for sampling error) as can be seen for the simple random and stratified random sampling. When bias is substantial, variance and mean-square error are quite different for example, for random and stratified random sampling with regression estimators when $1/D^2$ is the covariate. Estimated variances and mean-square errors for simple random sampling differ somewhat as can be seen across the row. This is strictly due to differences in sampling errors between the three runs of 2,000 samples.

Estimates can be improved dramatically if the appropriate covariate is used. This is true both when we stratify by the covariate or use it in regression. For example with D^2 as a covariate, the variance of the estimate for stratified sampling is 12.80 million which is only 33% of the variance of the estimate (38.52 million) for simple random sampling. This means that by using stratified sampling, we only need 1/3 the sample size of simple random sampling to get the same precision in estimation. Random and stratified random sampling with regression do even better. Their variance estimates are only 4% and 3% percent of the variance estimate for simple random sampling so we would only need 1/25 and 1/33 of the sample size used for simple random sampling to get the same precision. Note, that when we use an appropriate covariate such as D^2, that bias is inconsequential for any of the sampling strategies. In all four cases, the variance and mean square error are nearly identical.

When we use the less appropriate covariate D, we still obtain substantial improvements over simple random sampling. The stratified random, random sampling with regression estimator, and stratified random sampling with a combined regression estimator give variance estimates 36%, 11%, and 4% of the variance estimates for simple random sampling.

Comparing strategies using D^2 or D as covariate shows that it pays to use the more appropriate covariate. Our most precise estimate with D^2 was 20% more efficient than the one with D as covariate because volume is more correlated with basal area than diameter. This means we can have a 26% reduction in sample size if we use D^2 instead of D as a covariate and still get the same precision in estimation if in both cases we use stratified sampling with a combined regression estimator. For simple random sampling with regression, the difference is even more striking (64% better).

Using $1/D^2$ illustrates some of the dangers in using a covariate inappropriately (Table 1). The stratified random, random sampling with regression estimator, and stratified random sampling with a combined regression estimator give variance estimates 38%, 68%, and 37% of the variance estimator for simple random sampling. Certainly use of stratified random sampling appears to be highly efficient in estimation. But the regression estimators for both the random and stratified random sampling are badly biased. They estimate total volume to be 23,983 and

24,915, respectively, when we know that it is 25,989 cubic feet. Instead of comparing variances, compare mean-square errors. The mean-square errors for stratified sampling and stratified sampling with regression still look good compared to simple random sampling. But when we compare the results with those for D^2 and D it is clear that $1/D^2$ is much less desirable as a covariate.

The mean-square errors for stratified random, random sampling with regression, and stratified random sampling with a combined regression estimator using $1/D^2$ as a covariate are respectively 111%, 1,833%, and 1,352% of those for D^2 as a covariate.

Conclusion

In summary the following recommendations are offered:

1. In sample design and estimation, covariates should be used, if practically available, since their use can result in tremendous gains in precision in estimation at both the design and estimation stage.

2. Care should be taken to use the appropriate covariate to make the estimates of interest as precise as possible and to minimize bias in estimation. Plotting the variable(s) of interest against potential covariates is a useful tool to determine the type of relationship and the strength of that relationship. Additional independent variables (e.g., tree height in our example) can be added to improve the precision of the estimates.

3. It is safer to use a covariate in stratification than in regression. The use of a covariate in stratification does not bias estimation whereas covariates used inappropriately will seriously bias regression estimation.

References

Cochran, W. G. 1977. Sampling Techniques. Third Edition, John Wiley and Sons, N.Y. 428 pp.

Freese, F. 1962. Elementary forest sampling. Agriculture Handbook 232. USDA Forest Service. 91 pp.

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CURRENT LITERATURE

Please order directly from sources given in ( ). In case of journal articles, contact your local library for availability.

GENERAL

Information Reports Digest -- a new publication presenting abstracts of all Information Reports being published by the Canadian Forestry Service. (To be placed on the mailing list contact: Information Team, Environment Management Service, Dept. of the Environment, Ottawa, Ontario, Canada, K1A OE7).

Midriak, Rudolf. 1979. Anti-avalanche protection of forests. Text in Slovak, summaries in English, German, and Russian. Lesnícke stúdie VULCH No. 27, 1977, 218 p. (Forest Research Institute, VULCH, 960 92 Zvolen, Marxova 2175, Czechoslovakia.)

1981. Mulga Research Centre Annual Report. 1980. 83 p. (Western Australian Institute of Technology, Haymen Road, Bentley, WA 6102, Australia).

Clark, Larry R. et al. 1980. Is the water getting cleaner? A survey of water quality in the Tennessee Valley. 32 p. (Division of Water Resources, Office of Natural Resources, Tennessee Valley Authority, 116 Evans Building, Knoxville, TN 37901).

Bolsinger, Charles L. 1980. California forests: Trends, problems, and opportunities. USDA Forest Service Resource Bulletin PNW-89. 138 p. (Pacific Northwest Forest and Range Exp. Stn., 809 NE 6th Ave., Portland, OR 97232).

Felt, Dorothy G. 1980. Forest area and timber resource statistics for the Bear River and Wasatch Front Working Circles, Utah, 1976-1977. USDA Forest Service Resource Bulletin INT-22, 25 p.

Felt, Dorothy G. 1980. Forest area and timber statistics for the mountain lands and Uinta Basin Working Circles, Utah, 1977-1978. USDA Forest Service Resource Bulletin INT-23, 24 p. (Both available from Intermountain Forest and Range Experiment Station, 507 25th St., Ogden, UT 84401).

Buszewicz, Guidon. 1980. Seed bank, seed supply and cooperation with tree nurseries. Escuela Nacional de Ciencias Forestales. Technical Note 1. 4 p. (In Spanish).

Mankins, Jerome. 1980. Bark beetles of the conifers of Central American. General Ips. Escuela Nacional de Ciencias Forestales. Technical Note 2. 4 p. (In Spanish).

Hazlett, D. L., and J. L. Montesinos. 1980. Growth of 27 broadleaf species in old plantation in Lancetilla Botanical Garden. Escuela Nacional de Ciencias Forestales. Scientific Article 1. 9 p. (In Spanish).

Houkal, Dana. 1980. Provenance behavior of Pinus pseudostrobus Lindl in ESNACIFOR nursery in Siguatepeque, Honduras, C.A. Escuela Nacional de Ciencias Forestales. Scientific Article 2. 11 p. (In Spanish).

CODEFOR. 1981. Honduras Forestal. Corporación Hondureña de Desarrollo Forestal. No. 7. 31 p. (The 5 above publications are available from Escuela Nacional de Ciencias Forestales, CODEFOR, Apartado Postal No. 2, Siguatepeque, Depto. De Comayagua, Honduras).

1980. Streamside Areas - Management Dividends. FWS/OBS - 80/55. 8 p. (U. S. Fish and Wildlife Service, WELUT, Drake Creekside Building, 2625 Redwing Road, Ft. Collins, CO 80526).

1981. Management Report on Strategic Planning for Human Resources: 1980 and Beyond. 124 p. (For information on the report's availability, contact Karen Smolens, Center for Management Research, 850 Boylston St., Chestnut Hill, MA 02167. Phone (617) 738-5020).

1980. America's Soil and Water: Condition and Trends. 32 p. (U. S. Dep. Agric., Soil Conservation Service, Washington, D. C. 20250).

ANALYSIS

Davis, S. E., and K. S. Arney. 1981. Computer-assisted spatial analysis as applied to deer management in Tennessee: A case history. Presented at the Fourth Annual Meeting of the Southeast Deer Study Group, February 16-18, 1981, sponsored by the Florida Game and Fresh Water Fish Commission. (From Stanford E. Davis, Tennessee Valley Authority, Division of Land and Forest Resources, Norris, TN 37828).

Buongiorno, Joseph, and David J. Ohms. 1978. FSTAT: a system for storage, retrieval and analysis of international forestry and agriculture statistics. Res. Bull. R2930, 49 p. (Agriculture Bulletin Bldg., 1535 Observatory Dr., Madison, WI 53706).

Johnstone, W. D., and E. B. Peterson. 1980. Above-ground component weights in Alberta populus stands. Information Report NOR-X-226, 18 p. (Northern Forest Research Center, Canadian Forestry Service, 5320 - 12th St., Edmonton, Alberta, Canada T6H 3S5)

Honeycutt, Dale M., Kristina M. Brooks, and A. Jon Kimerling. 1980. Geographic information systems: A review of selected operational and functional capabilities. 72 p. (Geography Dept., Oregon State Univ., Corvallis, OR 97331).

Phillips, D. R., and J. R. Saucier. 1979. A test of prediction equations for estimating hardwood understory and total stand biomass. Georgia Forest Research Paper. 7. 8 p. (USDA For. Service, Southeastern Station, Asheville, NC 28802).

Billings, R. F., and B. G. Hynum. 1980. Southern pine beetle: Guide for predicting timber losses from expanding spots in East Texas. Circular 249. (Texas Forest Service, I. and E. Dept., P. O. Box 310, Lufkin, TX 75901).

Swindel, B. F., C. A. Hollis, L. F. Conde, and J. E. Smith. 1979. Above-ground live biomass of slash pine trees in natural stands. Impus Report 4(1): 1-16. (USDA For. Service, Southeastern Forest Experiment Station, University of Florida, Gainesville, FL 32611).

INVENTORY

Galitsky, V. V. 1980. On the determination of living tissue mass in higher plants. 17 p. Text in Russian, summary in English.

Galitsky, V. V. 1980. The plane geometrical structure as a control factor of the plant community structure. In Systems Analysis and Simulation. Proc. Inter. Symp., Berlin, GDR. Sept. 1-5, 1980. p. 434-435. (Contact the author for the above 2 publications at Inst. of Agrochemistry and Soil Science, USSR Acad. of Science, 142292 Puschino Moscow Reg., USSR).

Arner, S. L. 1980. MISSING, a computer program for the maximum likelihood estimates of the parameters of the multivariate linear model with incomplete measurements. 9 p. (USDA For. Serv. Northeastern Forest Experiment Station, Broomall, PA 19008).

Tamminen, Zachris. 1979. Wood measurements in the USSR, including some general comparisons between Swedish and Soviet practice. Report No. R111. 39 p. (Swedish University of Agricultural Sciences, Dept. of Forest Products, Box 7008, S-750 07 Uppsala, Sweden).

Taulbee, John D., and M. J. Symons. 1980. Sample size and duration for cohort studies of survival time with covariables. Mimeo. Series No. 1300. August. 26 p. (Department of Biostatistics, University of North Carolina, Chapel Hill, NC 27514).

Pollock, K. H. 1980. Capture-recapture models: A review of current methods, assumptions and experimental design. Mimeo. Series No. 1308. 32 p. $3.20. (Institute of Statistics, North Carolina State University, Box 5457, Raleigh, NC 27607).

1979. Summary booklet. International Statistical Institute. Invited papers. 119 p. (Iass-Aise, 18 Boulevard Pinard, 75675 Paris Cedex 14; France).

Rogers, Robert. 1980. Evaluating stocking in upland hardwood forests using metric measurements. 5 p. (USDA Forest Service, North Central Forest Experiment Station, 1992 Folwell Ave., St. Paul, MN 55108).

REMOTE SENSING

Rose, Paul W., and Peter C. Resendahl. 1980. Application of Landsat digital data for classification of wetland areas in Shark River Slough, Everglades National Park, Florida. Final Technical Report. U. S. National Park Service, South Florida Research Center, Everglades National Park, Homestead, FL 33030. 18 p. (User Services Section, USGS, EROS Data Center, Sioux Falls, SD 57198).

Dottavio, C. L., D. L. Williams, B. L. Markham, and M. Labovitz. 1980. Sensor parameter study: Literature review and experimental plan. AgRISTARS report RR-GO-04009. Price unknown. (National Technical Information Service, Springfield, VA 22151). 21 p.

Grumstrup, P. et al. 1980. Assessment of powerline structure impact upon agricultural crop production with small format aerial photography. IAFHE RSL Research Report 80-3. 17 p. (U. of Minn., Remote Sensing Lab., 110 Green Hall, 1530 N. Cleveland Avenue, St. Paul, MN 55108).

Meyer, M., M. Heitlinger, and P. Grumstrup. 1980. Monitoring and mapping natural area grassland vegetation with small format aerial photography. IAFHE RSL Research Report 80-5. 11 p. (U. of Minn., Remote Sensing Lab., 110 Green Hall, 1530 N. Cleveland Ave., St. Paul, MN 55108).

CLASSIFICATION

Brown, David E., and Charles H. Lowe. 1980. Biotic communities of the southwest (map). (USDA Forest Service Gen. Tech. Report RM-78. 19 p. Rocky Mountain Forest and Range Experiment Station, 240 W. Prospect St., Fort Collins, CO 80526)

Canada Committee on Ecological Land Classification. 1980. Land/Wildlife integration - proceedings of a technical workshop to discuss the incorporation of wildlife information into ecological land surveys, 1 and 2 May 1979, Saskatoon, Sask. (comp. and ed. by D. G. Taylor). 160 p.

Clark, Ronnie. 1980. Erosion condition classification system. USDI Bur. Land Mgmt. Tech. Note 346, 47 p. (USDI Bur. Land Mgmt., Bldg. 50, Denver Federal Center, Denver, CO 80225).

Ducruc, J. P. 1980. The land system, basic unit in ecological mapping - survey of natural resources in the James Bay Territory (also available in French). 48 p.

Dyrness, C. T. and Leslie A. Viereck. 1980. A preliminary classification system for vegetation of Alaska. USDA Forest Service Gen. Tech. Report PNW-106. 38 p. (Publication Distribution, Pacific Northwest Forest and Range Experiment Station, 809 N.E. 6th Ave., Box 3141, Portland, OR 97208.)

Hoffman, George R. and Robert R. Alexander. 1980. Forest vegetation of the Routt National Forest in northwestern Colorado: A habitat type classification. USDA Forest Service Res. Paper RM-221, 41 p. (Rocky Mountain Forest and Range Experiment Station, 240 W. Prospect St., Fort Collins, CO 80526).

Jurdant, M. and J. P. Ducruc. 1980. Carte ecologique du territoire de la baie-James, districts ecologiques et geomorphologie.

Lands Directorate. 1980. Lands Directorate Publications. (Lands Directorate of Canada, Ottawa, Canada, K1A 0E7.)

Millar, J. B. 1976. Wetland classification in western Canada: a guide to marshes and shallow open water wetlands in the grasslands and parklands of the Prairie Provinces. 38 p. (Publishing Centre, Supply and Services Canada, Ottawa. $2.00 (Canada); $2.40 (other countries). Cat. No. CW65-8/37).

Romaine, M. J. and G. R. Ironside. 1979. Canada's Northlands. Proceedings of a technical workshop to develop an integrated approach to base data inventories for Canada's northlands, 17-19 April, 1974, Toronto, Ontario. Second edition. Ecological Land Classification Series, No. 0. 124 p. (Lands Directorate, Environment Canada, Ottawa, Canada K1A 0E7).

Rubec, C. D. A. and F. C. Pollett. 1980. Proceedings of a workshop on Canadian wetlands, June 11-13, 1979, Saskatoon, Sask. Wetlands Working Group of CCELC. 90 p.

Taylor, D. G. 1980. Land/wildlife integration. Proceedings of a technical workshop to discuss the incorporation of wildlife information into ecological land surveys, 1 and 2 May 1979, Saskatoon, Sask. Ecological Land Classification series, No. 11. 160 p. (Lands Directorate, Environment Canada, Ottawa, Canada, K1A 0E7.)

Turner, R. M., L. H. Applegate, P. M. Bergthold, S. Gallizioli and S. C. Martin. 1980. Arizona range reference areas. USDA Forest Service Gen. Tech. Report RM-79. 35 p. (Publication Distribution, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 240 W. Prospect St., Fort Collins, CO 80526.)

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MEETINGS, WORKSHOP, AND SYMPOSIA

June 1-5, 1981. Remote Sensing Techniques in Geology. Contact: Branch of Applications, EROS Data Center, Sioux Falls, SD 57198. Phone (605) 594-6114.

June 1-5, and July 13-17, 1981. Fundamentals of Applied Remote Sensing. Two separate 5-day courses. Contact: Anne Kahle, KARS Program, University of Kansas Space Technology Center, Lawrence, KS 66045. Phone (913) 864-4775.

June 9-11, 1981. Remote Sensing for Decision Makers. $350 (limited to 20). Contact: Prof. Warren R. Philipson, Cornell University, Hollister Hall, Ithaca, NY 14853. Phone (607) 256-4330.

June 23-26, 1981. Symposium on Machine Processing of Remotely Sensed Data - Special Emphasis on Forest, Range, and Wetland Assessment. Contact: Douglas B. Morrison, Purdue University/LARS, 1220 Potter Drive, West Lafayette, IN 47906. Phone (317) 749-2052.

June 26-October 2, 1981. Ninth Forest Research Course of the Commonwealth Forestry Institute. Contact: H. L. Wright, Dept. of Forest Science, Commonwealth Forestry Institute, Univ. of Oxford, Oxford, OX1 3RB, England.

July 7-10, 1981. Use of Programmable Calculators in Forestry. $400.

July 13-17, 1981. Regression Methods in Resource Analysis. $400.

July 20-24, 1981. Multilevel Sampling. $400. For information on all three of the above short courses, contact Office of Conferences and Institutes, W1 Rockwell Hall, Colorado State University, Fort Collins, CO 80523.

August 9-14, 1981. "In-Place Resource Inventories: Principles and Practices--A National Workshop." (Orono, Maine). $60. Sponsored by the Renewable Natural Resources Foundation, the Society of American Foresters, Society for Range Management, American Society of Photogrammetry, Wildlife Society, and in cooperation with the Forest Industries of Maine, University of Maine, the USDA Forest Service, Soil Conservation Service, USDI Bureau of Land Management, Fish and Wildlife Service, and Geological Survey. Contact: John Benoit, Conferences and Institutes Div., University of Maine, 128 College Ave., Orono, ME 04473. Phone (207) 581-2626.

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